INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01735

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H02K 1/30, H02K 7/102, H02K 21/22
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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DOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4677328 A1 (K.KUMAKURA), 30 June 1987 (30.06.87), figure 1, abstract --	1-6
Y	US 4785138 A1 (O.BREITENBACH ET AL), 15 November 1988 (15.11.88), see the whole document --	1-5
Y	US 4475075 A (R.MUNN), 2 October 1984 (02.10.84), figure 1, abstract --	6
A	US 4258280 A (M.STARCEVIC), 24 March 1981 (24.03.81), figures 1,2, abstract --	3,4,5

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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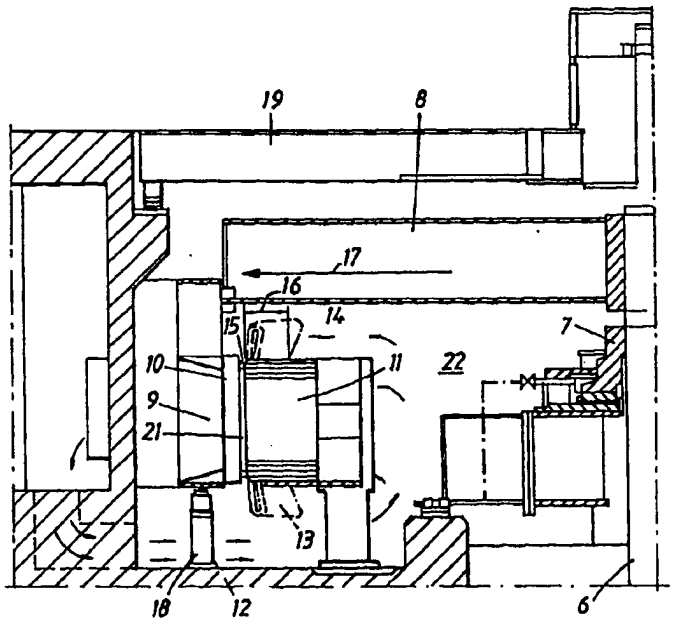
(54) Title: ROTATING ELECTRIC MACHINE WITH MAGNETIC CIRCUIT



(57) Abstract

The invention relates to a rotating electric machine having a magnetic circuit for high voltage. The machine has a stator (11), the winding of which comprises a high-voltage cable (1), and a rotor (9) surrounding the stator (11).

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ROTATING ELECTRIC MACHINE WITH MAGNETIC CIRCUIT

The rotating electric machines referred to herein comprise synchronous machines used primarily as generators for connection to distribution and transmission networks, in the following referred to as power networks. The synchronous machines are also used as motors as well as for phase compensation and voltage control and in that case as mechanically open-circuited machines. The technical field also includes dual-fed machines, asynchronous static current converter cascades, outerpole machines and synchronous flow machines. These machines are intended for use with high voltages. High voltages shall be understood here to mean electric voltages in excess of 10 kV. A typical operating range for the machine according to the invention may be 36 to 800 kV.

The use of high-voltage insulated electric conductors in the stator winding, the conductors in the following being termed cables, with solid insulation similar to that used in cables for transmitting electric power (e.g. PEX cables), enables the voltage of the machine to be increased to such levels that it can be connected directly to the power network without an intermediate transformer. The need for fast, continuously adjustable reactive power is thus satisfied, connected directly to subtransmission or transmission level in order to deal with system stability and/or the dependence of rotating mass and e.m.f. in the vicinity of high-voltage direct current transmissions or, alternatively, to generate or consume high-voltage alternating current connected directly to subtransmission or transmission level. The station may be for a few MVA up to thousands of MVA.

The obvious advantage is that transformers in which the reactance consumes reactive power are unnecessary, as are also traditional high-power circuit breakers. Advantages are also gained with regard to network quality since rotating compensation is obtained, and with regard to overload capacity which may be +100% in such machines. The control range may be +100% for reactive power.

However, problems may arise since the stator winding in such a high-voltage machine, with cable of the type described, acquires considerable radial dimension. At a given diameter of the machine's air gap, the diameter increases in proportion to the number of turns of the winding and

the slots in the stator laminations carrying the cable must be deep and the stator laminations numerous.

The object of the present invention is to solve the above-mentioned problems and provide a machine with a smaller stator and thus an arrangement which is smaller in dimension but not in power. This object is achieved by the machine according to the invention being given the characteristics defined in the claims.

The invention will be described in more detail with reference to the accompanying drawings, in which

Figure 1 shows a cross section through a cable used in the invention,

Figure 2 shows an axial section through a machine according to the invention, designed as a hydroelectric generator,

Figure 3 likewise shows an axial section through a second embodiment of the machine according to the invention,

Figure 4 likewise shows an axial section through a third embodiment of the invention according to the invention, and

Figure 5 likewise shows an axial section through a fourth embodiment of the invention according to the invention.

The invention is in the first place intended for use with a high-voltage cable 1 of the type (Fig. 1) built up of a core having a plurality of strand parts 2, an insulating layer 4 surrounding the inner semiconducting layer, and an outer semiconducting layer 5, and its advantages are particularly pronounced here. The invention refers particularly to such a cable having a diameter within the interval 20-200 mm and a conducting area within the interval 80-3000 mm^2. The cable therefore does not include the outer sheath that normally surrounds a cable for power distribution.

The insulated conductor or high-voltage cable used in the present invention is flexible and is of the type described in more detail in WO 97/45919 and WO 97/45847. The insulated conductor or cable is described further in WO 97/45918, WO 97/45930 and WO 97/45931.

Accordingly, the windings, in the arrangement according to the invention, are preferably of a type corresponding to cables having solid, extruded insulation, of a type now used for power distribution, such as XLPE-cables or cables with EPR-insulation. Such a cable comprises an inner conductor composed of one or more strand parts, an inner semicon-

ducting layer surrounding the conductor, a solid insulating layer surrounding this and an outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an important property in this context since the technology for the arrangement according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of an XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

The winding should be constructed to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this context. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE-cable, for instance, the insulating layer consists of cross-linked, low-density polyethylene, and the semiconducting layers consist of polyethylene with soot and metal particles mixed in. Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having resistivity within the range of 10^{-1}-10^{6} ohm-cm, e.g. 1-500 ohm-cm, or 10-200 ohm-cm, naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene ("TPX"), cross-linked materials such as cross-linked polyethylene

(XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber (EVA/NBR), butyl graft polyethylene, ethylene-butyl-acrylate copolymers (EBA) and ethylene-ethyl-acrylate copolymers (EEA) may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of $E<500$ MPa, preferably <200 MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks appear, or any other damage, and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as in the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently high to enclose the electrical field within the cable, but sufficiently low not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

In Figure 1, illustrating the insulated conductor or cable, the three layers are executed so that they adhere to each other even when the cable is bent. The cable shown is flexible and this property is retained throughout the life of the cable.

Figure 2 shows in axial section a first embodiment of a rotating high-voltage machine according to the invention, in this case in the form of a hydroelectric generator. The rotor spokes 8 are attached on the turbine shaft 6 which, in this case, is journalled in a single guide bearing 7. These spokes support the rotor 9 with its excitation winding 10. The stator 11 is supported from below on a fixed foundation 12, and coil ends 14 of the stator winding 13 protrude from the stator 11.

In comparison with high-voltage machines proposed earlier, thus, the stator and rotor have exchanged places on each side of the air gap 15. This means that the slot depth 16 for the stator winding 13 will be smaller, and also the number of stator laminations will be fewer for a given air gap diameter 17.

18 denotes brakes for the rotor 9, arranged on the fixed foundation 12 for friction engagement with the rotor. The arrows in Figure 2 indicate the flow of cooling air through the stator 11.

The poles 21 on the rotor are pronounced and since they are placed on the inside of the rotor 9, against the stator 11, the rotor ring can be run at high speed without risk of problems with regard to its strength as may otherwise be the case in the higher speed register.

Figures 3-5 show three other embodiments of the machine according to the invention, designed as a hydroelectric generator. These figures reveal various ways of utilizing the generator pit 22 with varying degrees of success. Figure 3 shows the stator 11 suspended from the fixed beam 19, while the rotor 9 is supported by spokes 8 arranged below the stator. In this case, however, two guide bearings 7 and 20 are required for the shaft 6.

Figure 4 shows a embodiment of the machine in which, as in Figure 3, the rotor spokes 8 are arranged below the stator 11. The generator pit 22 is utilized better and the total height is less since the spokes 8 are

inclined slightly upwards. However, two guide bearings 7 and 20 are still required.

Figure 5 shows an even more compressed embodiment with the spokes 8 still further inclined. The machine has thus been compressed to such an extent that one guide bearing 7 is sufficient.

The rotor 9 and stator 11 may be so dimensioned that at nominal voltage, nominal power factor and over-excited operation, the thermally based stator and rotor current limits are exceeded approximately simultaneously. However, they may also be dimensioned so that at nominal voltage, nominal power factor and over-excited operation, the thermally based stator limit is exceeded before the thermally based rotor current limit is exceeded. At nominal voltage, nominal power factor and over-excited operation, the machine preferably has 100% overload capacity for two hours. The synchronous reactance in transverse direction is suitably considerably less than the synchronous reactance in direct direction. The machine is suitably equipped with excitation systems enabling negative and positive excitation.

The stator-winding phases in the machine are preferably Y-connected. The Y-point of the stator winding can then be insulated and protected from over-voltages by surge diverters. However, the Y-point of the stator winding may be earthed with the aid of a third-harmonic filter, i.e. a suppression filter between Y-point and earth. The suppression filter may be so designed that it greatly reduces or even eliminates third-harmonic currents through the machine, while at the same time being dimensioned so that voltages and currents are limited in the event of faults in the system. The third-harmonic filter may be protected against over-voltages by surge diverters connected in parallel with the third-harmonic filter.

CLAIMS

1. A rotating electric machine having a magnetic circuit for high voltage, characterized by a stator (11) the winding of which comprises a high-voltage cable (1), and a rotor (9) surrounding the stator (11), the cable (1) comprising a flexible conductor surrounded by solid insulation having an inner layer with semiconducting properties, an insulating part and an outer layer with semiconducting properties.

2. A device as claimed in claim 1, characterized in that the layers are arranged to adhere to each other even when the cable is bent.

3. A machine as claimed in claim 1 or claim 2, characterized in that the rotor (9) is rigidly connected to the machine shaft (6) for out-going or in-going kinetic energy via spokes (17) extending past the stator (11).

4. A machine as claimed in claim 3, characterized in that the stator (11) is supported from below on a fixed foundation (12) and in that the rotor (9) is supported from above by spokes (8) extending over the stator (11) from the machine shaft (6).

5. A machine as claimed in claim 3, characterized in that the stator (11) is supported from above by fixed radial beams (19) and in that the rotor (9) is supported from below by spokes (8) extending below the stator (11) from the machine shaft (6).

6. A machine as claimed in claim 4 or claim 5, characterized in that the brakes (18) for the rotor are arranged on the fixed foundation (12) for friction engagement with the rotor (9).

7. A machine as claimed in any of claims 1-6, characterized in that the rotor (9) has pronounced poles (21).

Fig. 1

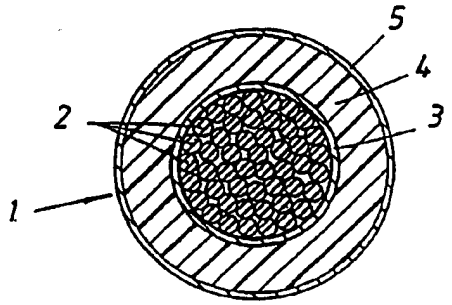


Fig. 2

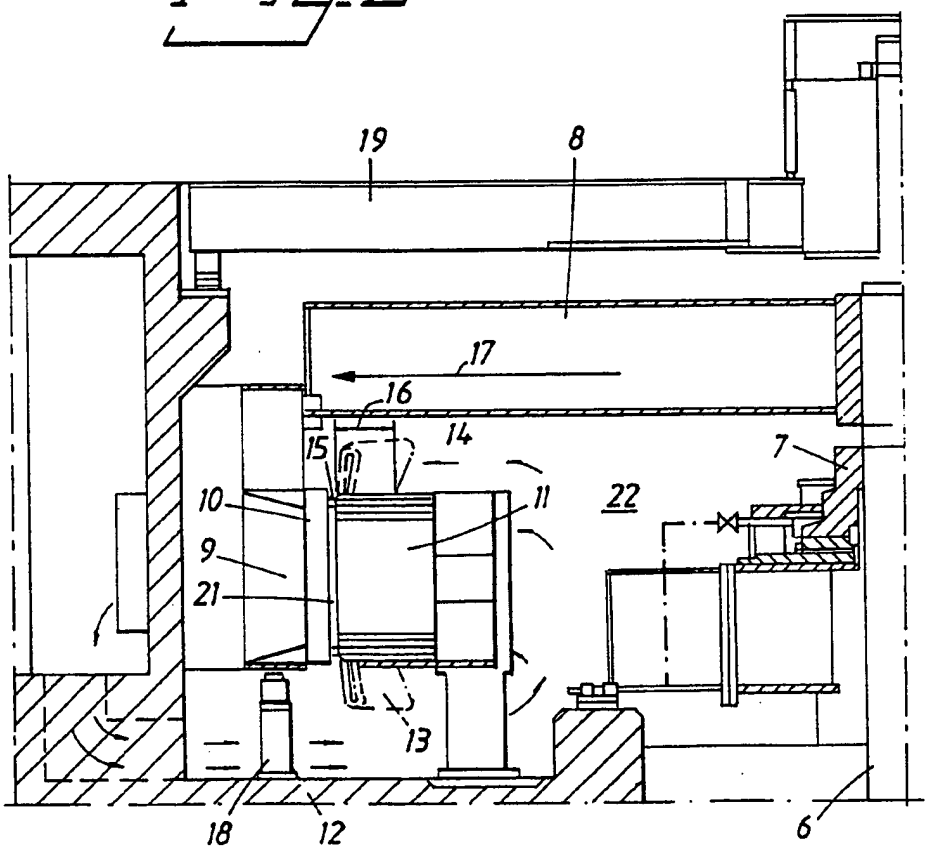


Fig. 3

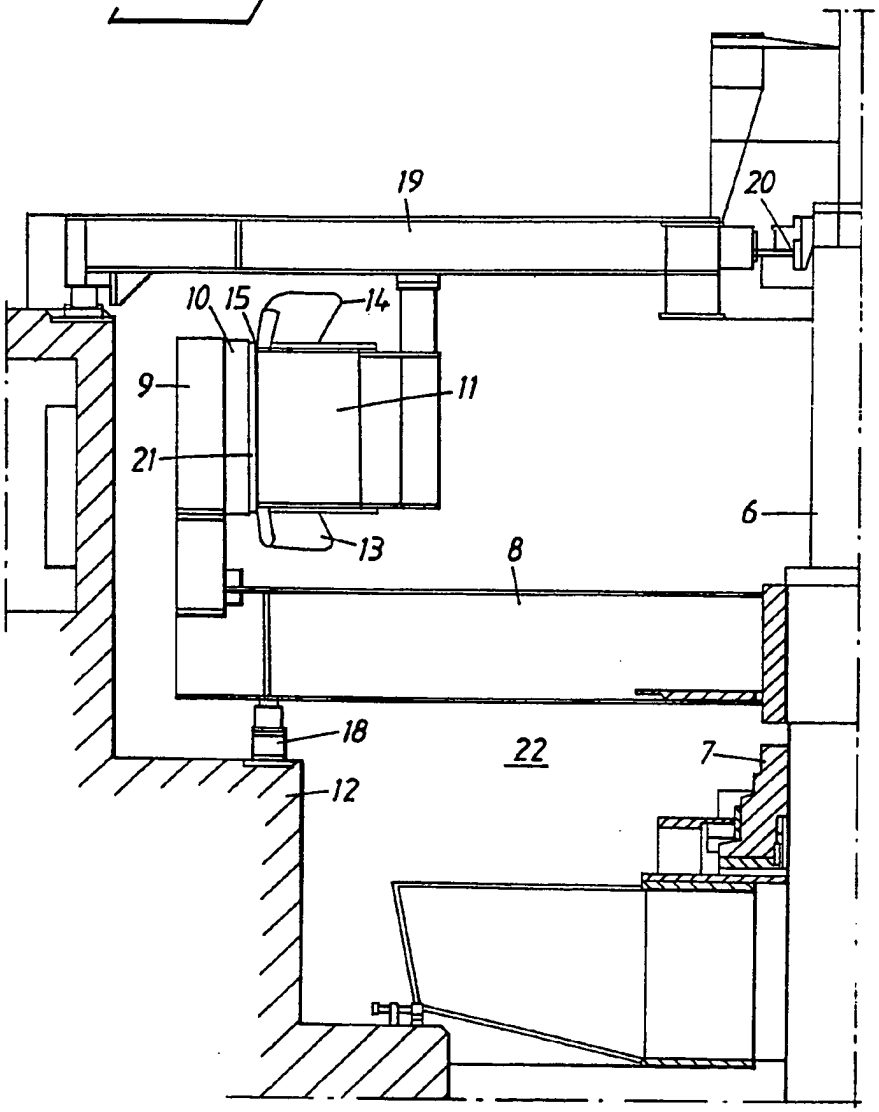


Fig. 4

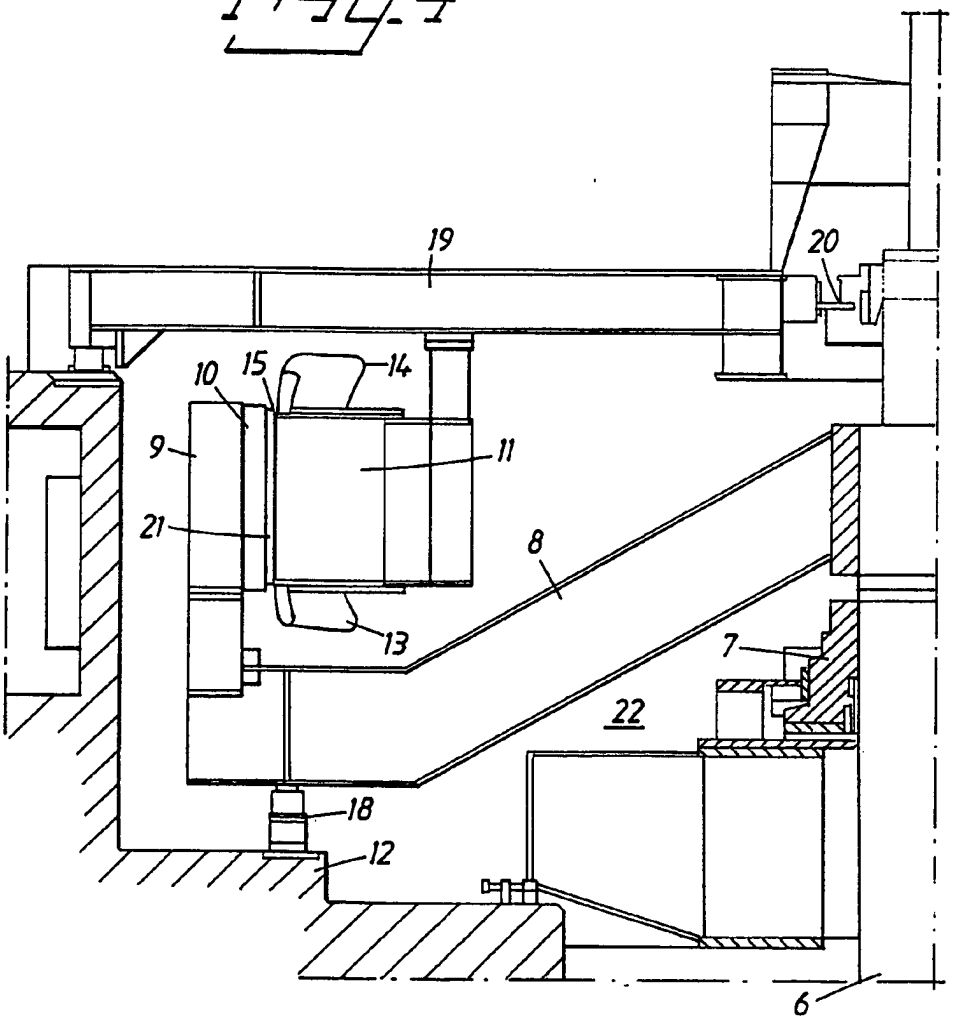
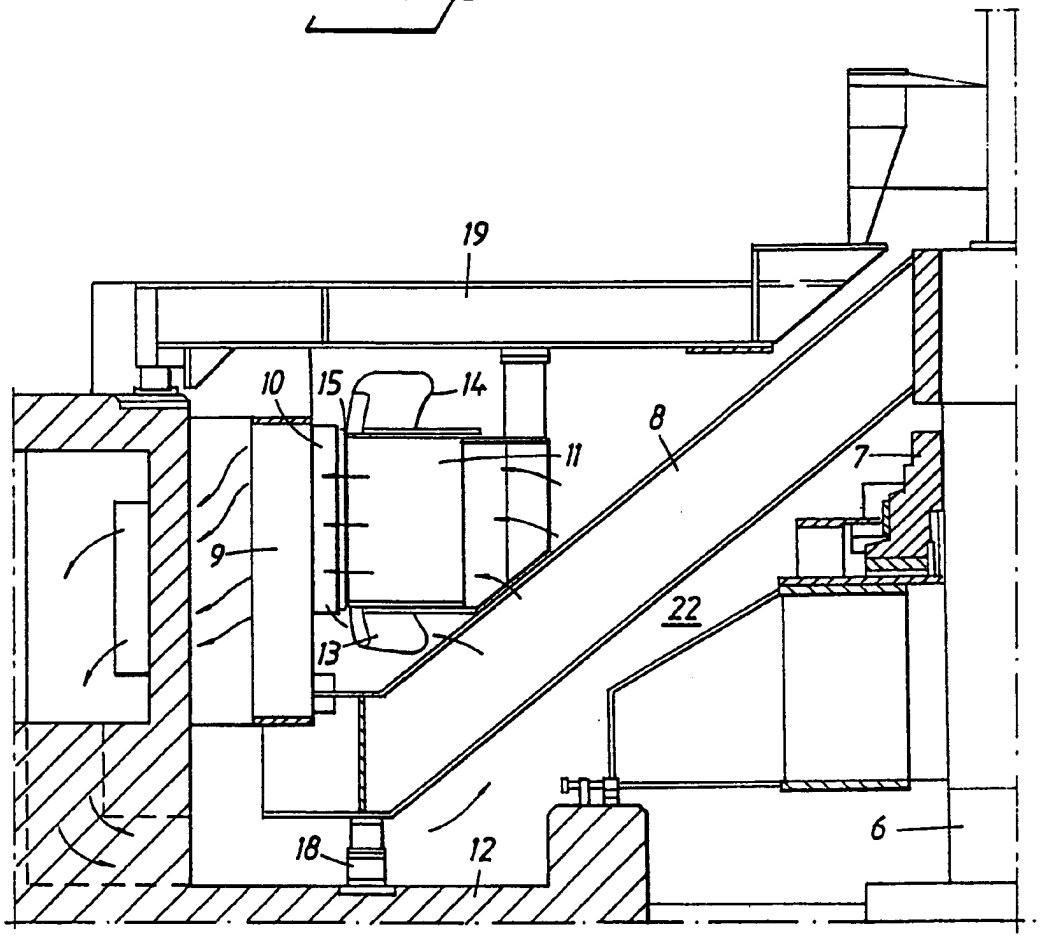


Fig.5



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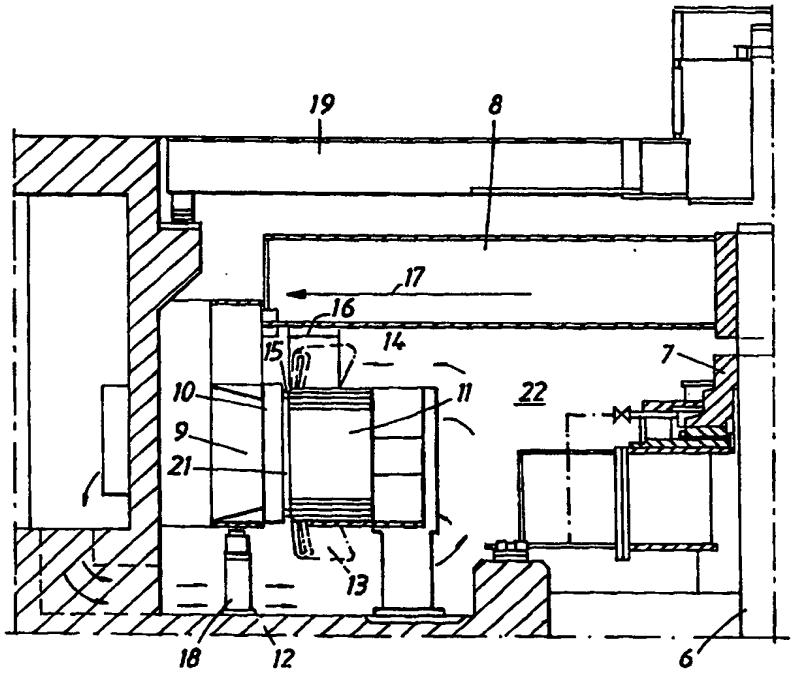

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8 December 1998	16 -12- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Karin Säfsten Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

09/509466

PATENT COOPERATION TREATY

RCD 14 DEC 1999

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
P 98-288 St/uh		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/SE98/01735	29.09.1998	30.09.1997
International Patent Classification (IPC) or national classification and IPC6		
H 03 K 3/00		
Applicant		
ABB AB et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 4 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of _____ sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☐ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- VI ☐ Certain documents cited
- VII ☐ Certain defects in the international application
- VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
26.04.1999	29.10.1999
Name and mailing address of the IPEA/SE Patent- och registreringsverket Box 5055 S-102 42 STOCKHOLM Telex 17978 PATOREG-S Facsimile No. 08-667 72 88	Authorized officer Tomas Erlandsson/AE Telephone No. 08-782 25 00

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE98/01735

I. Basis of the report

1. This report has been drawn on the basis of *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

☒ the international application as originally filed.

☐ the description, pages _____ , as originally filed,
pages _____ , filed with the demand,
pages _____ , filed with the letter of _____ ,
pages _____ , filed with the letter of _____ .

☐ the claims, Nos. _____ , as originally filed,
Nos. _____ , as amended under Article 19,
Nos. _____ , filed with the demand,
Nos. _____ , filed with the letter of _____ ,
Nos. _____ , filed with the letter of _____ .

☐ the drawings, ~~sheets~~/fig _____ , as originally filed,
~~sheets~~/fig _____ , filed with the demand
~~sheets~~/fig _____ , filed with the letter of _____ ,
~~sheets~~/fig _____ , filed with the letter of _____ .

2. The amendments have resulted in the cancellation of:

☐ the description, pages _____
☐ the claims, Nos. _____
☐ the drawings, ~~sheets~~/fig _____

3. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the supplemental Box (Rule 70.2(c)).

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/SE98/01735

V. Resoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-7	YES
	Claims		NO
Inventive step (IS)	Claims	1-7	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-7	YES
	Claims		NO

2. Citations and explanations

The claimed invention relates to a rotating electric machine for high voltages. The stator winding of the machine constitutes a flexible high voltage cable. The cable comprises a conductive core surrounded by two semiconducting layers and an intermediate insulating layer. By the use of a high voltage cable, a rotating electric machine can be connected to a power network without an intermediary transformer.

Documents cited in the International Search Report:

D1 US 4785138 A
D2 US 5036165 A

D1 discloses an electric cable for use as phase winding for a linear motor. That cable is flexible (column 1, line 67 - column 2, line 19) and it includes a conductive core surrounded by two conducting layers and an intermediate insulating layer (fig. 2). Additionally, the outer conductive layer is provided with a conductive sheathing.

In D2 a cable comprising a conductive core surrounded by two semiconducting layers and an intermediate insulating layer is disclosed. That cable is, for all practical purposes, not suitable fór using as a stator winding.

.../...

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Continuation of: Box V.

Independent claim 1 relates to a rotating electric machine in which a high voltage cable is used as a stator winding. The cable disclosed in D1 has the same characteristics as the cable of claim 1. Since that cable is meant to be used as winding in a linear motor, it could be argued that it might be obvious to use it as winding in an ordinary rotating electric machine. However, that cable is used in linear motors, which means that the voltages are below 10 kV. It is not indicated in D2 that a cable for linear motors could be used for the higher voltages, 36 kV-800 kV, used in the rotating electric machines according to the claimed invention. It can not be considered obvious for a person skilled in the art to both use a high voltage cable as a stator winding in a rotating electric machine and also realise that such high voltages could be applied that the machine could be directly connected to a power network without using an intermediary transformer. Consequently, the invention according to claim 1 is considered to involve an inventive step.

The invention according to claims 1-7 is new, is considered to involve an inventive step and has industrial applicability.

Copy for the Elected Office (EO/US)

PCT/SE98/01735

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

STOLT, Lars, C.
L.A. Groth & Co. KB
P.O. Box 6107
S-102 32 Stockholm
SUÈDE

Date of mailing (day/month/year)
23 September 1999 (23.09.99)

Applicant's or agent's file reference
P 98-288 St/uh

IMPORTANT NOTIFICATION

International application No.
PCT/SE98/01735

International filing date (day/month/year)
29 September 1998 (29.09.98)

1. The following indications appeared on record concerning:

[X] the applicant [ ] the inventor [ ] the agent [ ] the common representative

Name and Address
ASEA BROWN BOVERI AB
S-721 83 Västerås
Sweden

State of Nationality: SE
State of Residence: SE
Telephone No.:
Facsimile No.:
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [X] the address [ ] the nationality [ ] the residence

Name and Address
ABB AB
S-721 83 Västerås
Sweden

State of Nationality: SE
State of Residence: SE
Telephone No.:
Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer
I. Britel

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

United States Patent and Trademark Office
(Box PCT)
Crystal Plaza 2
Washington, DC 20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 09 June 1999 (09.06.99)	
International application No. PCT/SE98/01735	**Applicant's or agent's file reference** P 98-288 St/uh
International filing date (day/month/year) 29 September 1998 (29.09.98)	**Priority date** (day/month/year) 30 September 1997 (30.09.97)
Applicant ROTHMAN, Bengt	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

26 April 1999 (26.04.99)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Nicola Wolff
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38